

SELECTIVE REFLECTION IN THE INFRA-RED SPECTRUM

DISSERTATION

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JAMES TEMPLE PORTER



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By JAMES T. PORTER

Certain substances which transmit a large percentage of the incident radiation in the visible portion of the spectrum, reflect strongly in the infra-red. Of these, one of the most noteworthy is quartz. It has been shown by Professor E. F. Nichols¹ that in the neighborhood of wave-length $8.5\ \mu$ the reflection from a quartz surface is 20 or 30 times greater than in the other parts of the spectrum, and that, consequently, in the spectrum of rays after three successive reflections these waves will lose little in intensity, whereas those lying on either side of this value will be reduced in the ratio of $(20)^3$ or $(30)^3$ to 1. The spectrum, then, after three reflections will contain practically only the radiation of wave-length $\lambda = 8.5\ \mu$, and this in measurable quantity. Rubens and Nichols,² and Rubens and Aschkinass³ have employed this method, commonly known as the method of "Reststrahlen," for the detection of waves of great length in the infra-red.

In the work which has been done by these investigators it has been assumed that the positions of the reflection maxima and the absorption maxima coincide, and dispersion formulæ have been used in order to predict the positions of the reflection maxima. This

¹ *Physical Review*, **4**, 297, 1897.

² *Annalen der Physik*, **60**, 418, 430, 1897.

³ *Ibid.*, **65**, 241, 1898.

assumption is not entirely justifiable, and the agreement between the calculated and the observed values for the very long waves is not sufficiently conclusive. One of the objects of this research was to accumulate facts which might possibly throw some light upon the problem. The data, however, in regard to the dispersion of substances available for experiment are too limited to enable one to draw any conclusions. It is hoped, nevertheless, that the few facts here added may at some time prove useful in the solution of the problem.

The following is a list of the substances which have been studied by others and the wave-lengths of their *Reststrahlen* measured: quartz, fluorite, sodium chloride, sylvine, mica, marble, sodium bromide and calcium bromide. A detailed discussion of these is to be found in the papers referred to above. Each substance is characterized by well-marked maxima, which occur in the grating spectrum after three or more successive reflections. Fourteen other crystalline compounds have been examined by the writer. Seven of them, viz., potassium dichromate, copper sulphate, tartaric acid, ammonium chloride, potassium sulphate, potassium bisulphite, and potassium ferrocyanide, show unmistakable maxima at various parts of the spectrum. A few words with reference to each of these will be said after the apparatus has been described.

APPARATUS

Radiometer.—The radiometer was selected for this work because of the great difficulty in working in this laboratory with an instrument which is highly sensitive to small changes in the electric or magnetic conditions. This reason has barred the use of bolometer and thermopile, while the radiomicrometer, the only other instrument which can be used in work of this kind, for equal sensitiveness, is not so reliable as the radiometer. The latter instrument, undoubtedly the best for infra-red work in this laboratory, is objectionable on account of the absorption due to the fluorite plate. Above $11\ \mu$ practically no radiation gets through. With it, therefore, measurements cannot be made on waves whose wave-lengths exceed this value.

The instrument here described is in almost every respect similar to the one used by Professor Nichols at the Yerkes Observatory in the summer of 1900.¹ Two vertical sections at right angles to each

¹ *Astrophysical Journal*, 13, 110, 1901.

other are shown on the following page. The scale of the diagram is three-eighths natural size for all parts except the suspension, *H*, which is approximately three-fourths natural size. Tube *A* was cemented to

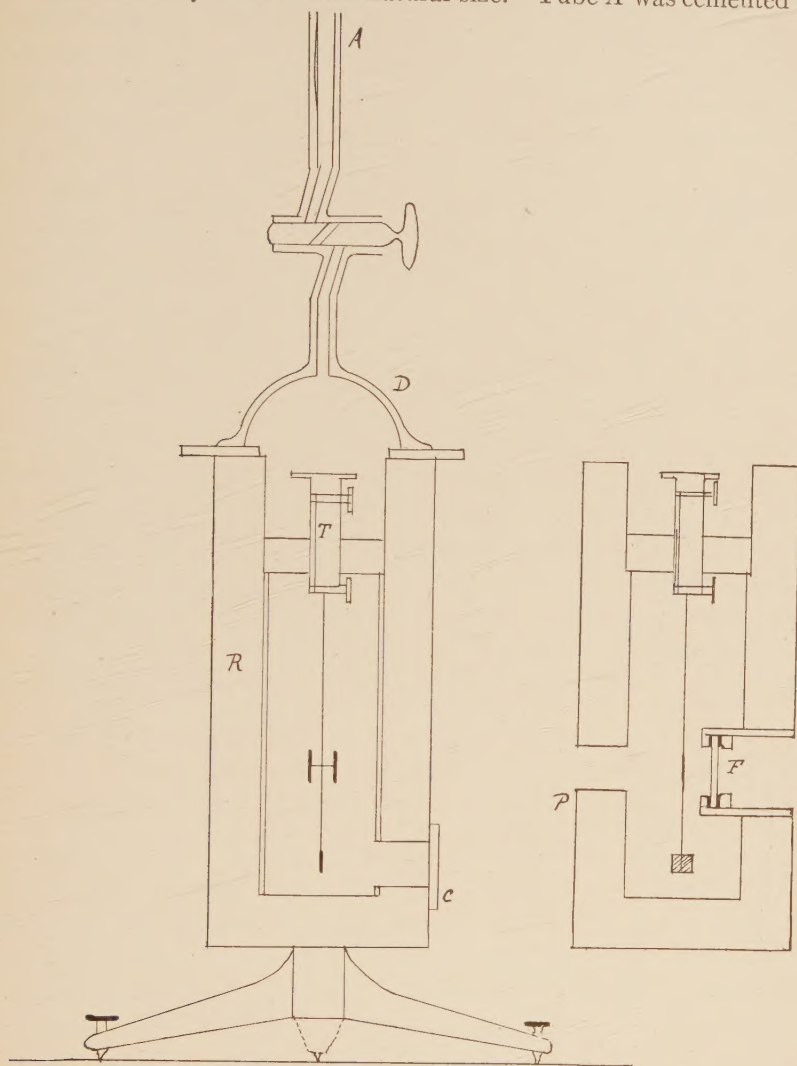


FIG. 1.—Diagram of Radiometer.

a drying tube containing phosphorus pentoxide with a Toepler mercury pump. On the frame supporting the pump was also placed a McLeod gauge which gave readings consistent to 0.001 of a milli-

meter of mercury. The openings at the lower end of the brass case *R*, three in number, were made air-tight in the following way: Over *C* and *P* glass plates were cemented by means of the rubber preparation ordinarily used for making stop-cocks air-tight. The window *F* was closed by means of a circular fluorite plate about 2 cm in diameter and 2 mm thick. This plate was placed between rubber washers, which had been previously smeared with the rubber preparation, and lowered into place at the inner end of a metal tube extending almost to the center of the case. A brass ring was then screwed down so as to hold the plate in place and secure an air-tight fit. The dome *D* was held in place by the same rubber preparation, and cemented to the glass connecting tube with Khotinsky cement. The rate of leak of the entire system, which contained besides these openings two stopcocks, amounted to about 0.003 mm in 24 hours, which is not large considering the number of possibilities for leakage.

The suspension.—The suspension was made in the following way: a very thin rod of glass about 3 cm long carried a cross-arm near its upper end. To the extremities of this arm were cemented, by means of hard shellac, rectangular mica vanes covered with lamp-black. The lower end of the vertical rod carried a small mirror placed at right angles to the plane of the vanes. A diagram and the exact dimensions are given below.

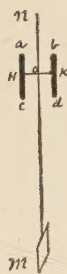


FIG. 2

$$mn = 32 \text{ mm}$$

Vane on the right of the diagram

Length = 0.5313 cm (mean)

Width = 0.0685 cm (mean)

Area = 3.637 sq. mm

Vane on the left of the diagram

Length = 0.5305 cm

Width = 0.0687 cm (mean)

Area = 3.641 sq. mm

ab (outside measurements) = 0.5401 cm

cd (outside measurements) = 0.5427 cm

Mean = 0.5414 cm

$\frac{1}{2} \times 0.5414 = 0.2707$ cm

OH (measured) = 0.2728 cm

Size of mirror = 3 × 3 sq. mm

Total weight = 6 $\frac{3}{4}$ mg.

A quartz fiber attached the suspension to the torsion head.

Sensitiveness.—In the radiometer it is well known that there is a critical pressure at which the sensitiveness is a maximum. The accompanying curve shows the relation existing between sensibility and pressure for the instrument under consideration. Abscissæ are pressures, ordinates are deflections. In plotting this curve there was used a 76-volt, direct current Nernst filament supplied by a storage battery with a constant current of 0.32 of an ampere. At the time

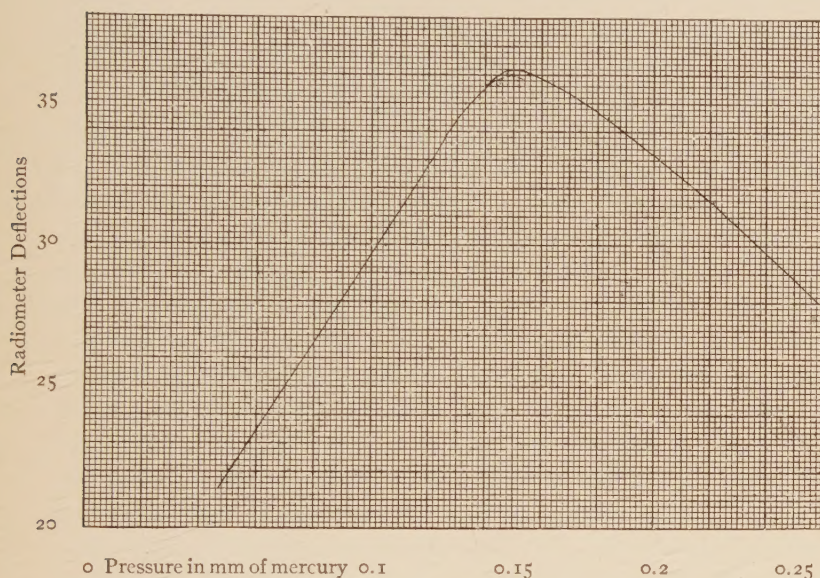


FIG. 3.—Sensibility Curve of Radiometer.

the observations were made the battery was being used for no other purpose. It will be observed that the maximum sensibility falls at about 0.15 of a millimeter. This critical pressure varies greatly in different instruments. Values ranging from 0.05 mm in Nichols' radiometer to 0.15 mm in this case, are to be found. It has been suggested that the McLeod gauges which have been used to measure the pressure are responsible for the discrepancy.

The sensitiveness was also tested by means of a paraffin candle in order to compare it with that of other instruments of a similar construction. The three radiometers compared in the following table are: radiometer used by Nichols¹ at the Yerkes Observatory

¹ E. F. Nichols, *loc. cit.*

in 1900; one used by Stewart¹ at Cornell in 1901; radiometer used in this investigation. The deflections have been reduced so that the numbers correspond to deflections on a scale one meter from the mirror due to a candle one meter from the vane.

COMPARISON OF SENSIBILITIES OF VARIOUS RADIOMETERS

COMPARISON SOURCE—A PARAFFIN CANDLE

By Whom Constructed	Vanes	Area of Vane in sq. mm	Deflection (Candle and Scale 1m off)	Deflection per sq. mm	Relative Sensibilities	Time Required for Maximum Deflection in Seconds
Nichols.....	Mica	3.14	395	126	1.0	5.5
Stewart.....	Platinum	30.00	1467	49	0.4	40.0
Stewart.....	Mica	30.00		...	1.5	300.0
Porter.....	Mica	3.64	1000	275	2.0	45.0

Difficulties.—The difficulties met with in working with a radiometer have several times been enumerated, but a few words with reference to them in the present case may not be out of place. In general troubles arise from four sources: namely, (1) unsteadiness of the zero position, (2) mechanical jarring, (3) leakage of the radiometer case and connections, and (4) static charges on the vanes. Leakage and charges on the vanes gave practically no trouble after the instrument was finally gotten into working condition. The rate of leak, as has been seen, was too small to be in the least annoying, and the size of the vanes permitted them to be placed at such a distance from the fluorite window that, while still fulfilling the conditions of sensitiveness, they could turn completely round without striking against it and consequently becoming charged, as frequently happens in the case of larger suspensions.

Unsteadiness of the zero position has given far more trouble. In so sensitive an instrument it is to be expected that such a difficulty will arise. This variation of the zero in the radiometer may be reduced in two ways: (1) by care in the construction of the suspension, and (2) by guarding against irregular distribution of the radiant energy reflected from objects situated obliquely in front of the fluorite window.

If the suspension were perfectly symmetrical with reference to the

¹ *Physical Review*, 13, 263, 1901.

axis of rotation, any source of radiation, no matter how intense, to which the vanes are equally exposed, should produce no effect. It is, however, not possible to secure perfect symmetry; therefore deflections may arise due either to the unequal absorption of radiant energy by the vanes, or to inequality in the length of the two arms, or to both these causes combined.

Furthermore, the vanes are located at the inner end of a comparatively long tube; consequently, if the objects situated obliquely in front of this tube radiate unequally, it is possible that both vanes may not be at the same time exposed to the action of equal forces. There will therefore result a rotation. This difficulty may be overcome by resorting to screens which will assist in securing a uniform distribution of the energy in the neighborhood of the radiometer. The figures given above give some idea in regard to the symmetry of the suspension, and the diagram of the apparatus shows the positions of the sheet-iron screens about the radiometer.

The source of the greatest annoyance has been mechanical jarring. The radiometer as well as other parts of the apparatus was supported upon marble slabs resting upon iron bars built into the wall of the laboratory. Nevertheless it was impossible to make observations during the day time. In the experiments on the *Reststrahlen* the readings were all taken between the hours of 8 P. M. and 12 P. M., when there was no other person in the building. Even under these conditions much time was lost in waiting for the effects of passing cabs to subside. I have found that when perfect quiet is obtained the deflections of this instrument are entirely reliable to one-tenth of a millimeter on a scale one meter off.

The spectrometer.—The divided circle used is one which has been employed in this laboratory for testing small plane gratings. This circle was set upon a heavy iron base and a steel arm so mounted that it, together with the circle, could be rotated in a horizontal plane about an axis passing through the center of the circle. This arm carried three things: (1) a small concave mirror of 52 cm radius of curvature, made by Bausch & Lomb, (2) a Nernst filament, the ballast being placed on the wall, and (3) a wire grating so mounted that the axis of rotation lay in the plane of the wires. The second mirror of the spectrometer, which was of the same size and make as

the one mentioned above, was fixed. The arrangement of the apparatus is shown by the diagram on the following page, which represents a horizontal section.

The letters indicate the following:

A, spectrometer table.

n, Nernst filament.

Q, sheet-iron screens.

W, steel bar.

m, m, silver-on-glass concave mirrors.

G, grating.

K, movable screen operated by a string in the hand of the observer at *H*.

V, V, verniers.

S, slit.

*S*₁, *S*₂, *S*₃, surface under consideration.

M, large silver-on-glass concave mirror.

R, radiometer.

C and *D*, switches in the incandescent lamp circuits.

F, a resistance box.

L, a brass rod by means of which the bar *W* can be turned about *O*.

T, a telescope for reading the radiometer deflections.

T', a telescope for reading the vernier.

B, an ammeter indicating the strength of the current through the Nernst filament.

I, a sheet-iron screen surrounding the radiometer and mirror.

P, a plane silver-on-glass mirror.

The large mirror *M* was made by Bausch & Lomb, and has a diameter of 12 cm and a radius of curvature of 26 cm.

In order to read the vernier *V* by means of the telescope *T'*, a small plane mirror was mounted above it making an angle of 45° to the vertical. A miniature incandescent lamp, which could be turned on and off by means of a switch near the observer at *H*, illuminated the scale and vernier. It can be seen from the arrangement of the apparatus that while taking a series of readings it is entirely unnecessary for the observer at *H* to change his position and this rarely occurred.

The source.—The source was a 76-volt, 0.44 of an ampere direct

current Nernst filament supplied by a storage battery, which, while readings were being taken, was in use for no other purpose save for supplying the 14-volt incandescent lamps which illuminated the

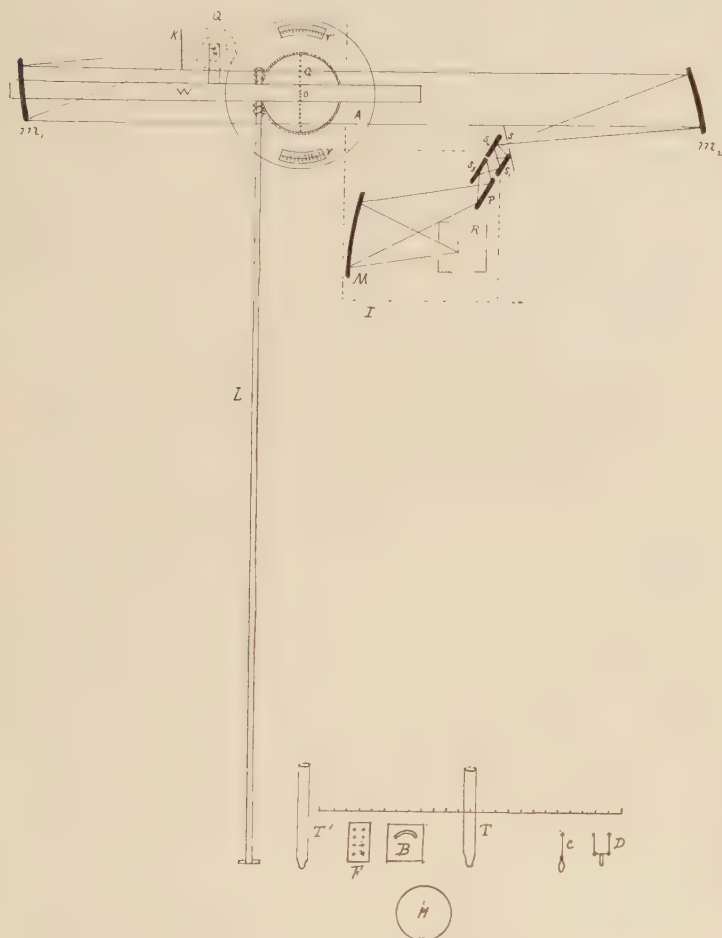


FIG. 4.—Diagram of Apparatus.

scale and vernier. These, as a rule, were kept burning continuously during a series of observations.

The source circuit contained in series a resistance box and milliammeter so placed that the current could be watched, and if necessary controlled, while readings were being taken without the observer's

moving from position. The current variation was very small, never exceeding a hundredth of an ampere and frequently absolutely no change in the reading of the ammeter could be detected.

The grating.—The grating was made in a way similar to that described by Rubens and DuBois in *Naturwissenschaftliche Rundschau*, 8 (No. 36), 1893. A heavy brass frame, represented in the diagram,

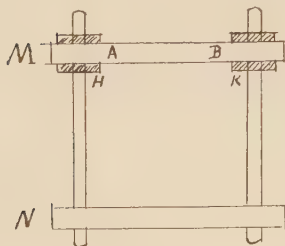


FIG. 5.

was placed in a lathe, the ends of two wires of as nearly the same diameter as possible soldered at *A*, and wound under tension about *M* and *N*. After perhaps five centimeters of the length of the frame had been covered in this way, the wires were soldered at *B* and the whole stretched by means of nuts *H* and *K* provided for the purpose. One of the wires was then cut and carefully unwound, while the remaining one was made fast to the brass pieces *M* and *N* by depositing electrolytically upon them a comparatively heavy coating of copper. This done, the wire on one side was cut away. The spacings between the wires of a grating made in this way are very nearly equal to the diameter of the wire. The grating constant was determined by means of a dividing engine as follows: A setting was made on the edge of each wire and the value of each space determined for the whole grating. The mean of these values was then averaged with the value of the constant found by taking the first and last readings and dividing the difference between them by the number of spaces. The value of the constant for the grating used in the wavelength determination was found to be 0.2414 of a millimeter.

Adjustments were made in the following way. After having first placed the grating *C* so that the plane of the wires included the prolongation of the axis of rotation, as nearly as this direction could be determined, the mirror *m* was moved along *W* until the reflected beam became parallel, then rotated about a vertical axis until normal incidence upon the grating was secured. By means of *m* the spectrum was brought to a focus in the plane of the slit *S*. These adjustments having been made, it was then only necessary to turn the rod *L* in order to bring any desired portion of the spectrum upon the

slit. If the slightest change in the angle of deviation was to be indicated by the radiometer, it was necessary that the image of the filament and the slit S should have exactly the same width, and since the mirrors m_1 and m_2 had the same focal lengths, S had to have a width equal to the diameter of the filament in order to secure this result. This width was generally slightly less than one millimeter.

As soon as the current begins to flow through a Nernst filament the filament twists out of its original position. Observation showed, however, that after the current had once started and the filament had been adjusted parallel to the slit there was no relative shift of the image and slit during a series of observations.

The surfaces S_1 , S_2 , S_3 , supported on comparatively heavy iron blocks, resting on a wooden platform, were placed at about the angle represented in the diagram, no special care, however, being taken to secure accuracy in this respect. The mirror M focused the image of the filament on the radiometer vane which was slightly smaller than the image itself.

The method of measurement is this: note the spectrometer reading when the central image is focused on the vane, pass the spectra

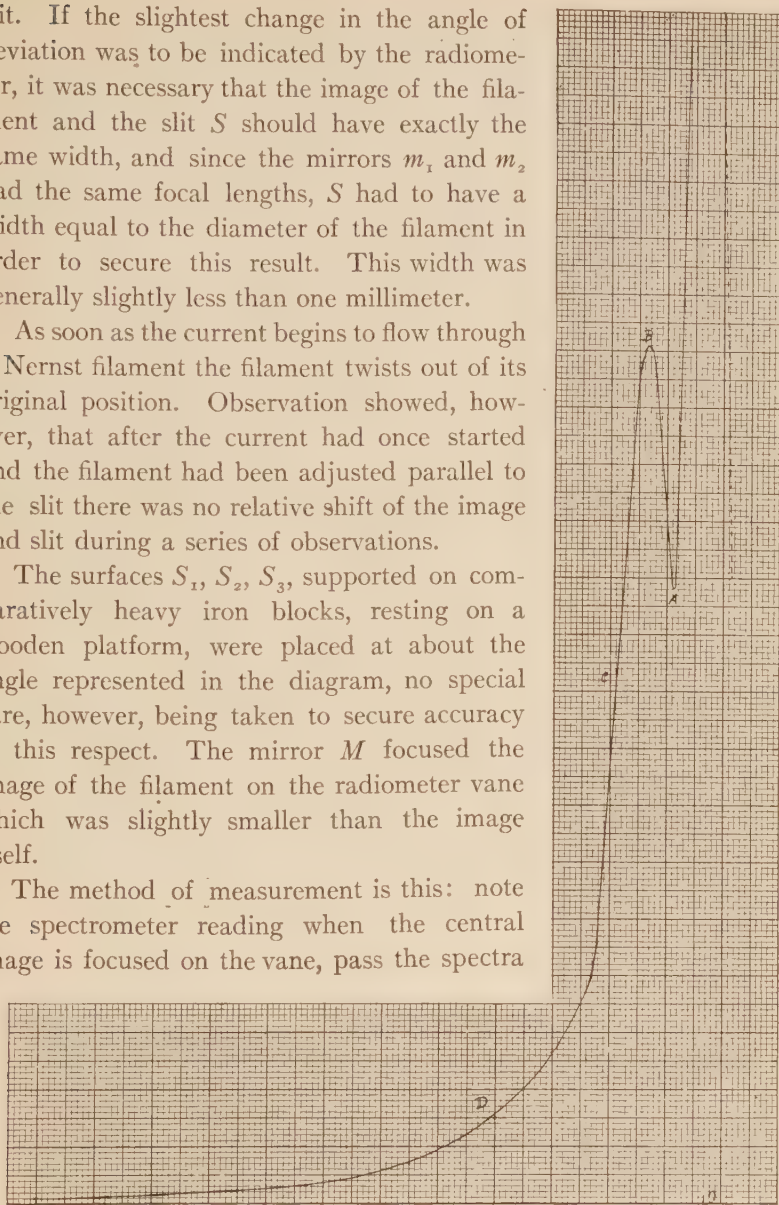


FIG. 6.—Curve showing the distribution of energy in the grating spectra of a 76-volt, direct current, Nernst glower. Abscissae are angles of deviation; ordinates are radiometer deflections.

Scale: Abscissae, 1 small division = $2'$;

Ordinates, 1 small division = 1 mm on radiometer scale.

across the slit by turning L , and if the surfaces show selective reflection for a particular wave-length, the deflections of the radiometer will rise to a maximum as that portion of the spectrum falls on the slit. The difference between the spectrometer readings in the two cases is the angular deviation times the grating constant, order, gives the wave-length. measurements it was thought had already been made. For plates, 4×4 cm, were placed in the diagram. The sensibility of the aperture of the mirror considerably in order to bring range of the scale. The determined from the position was 8.14μ . Since this according to the measurements of Nichols, and since no exercise in procuring nor

tion. The sine of this angle if the spectrum be the first

Before making any new best to repeat some which this purpose four quartz at the points indicated in the the radiometer was such m had to be reduced the deflections within the value of the wave-length of the first maxima value was much too low measurements of Rubens and special care had been mal incidence upon the

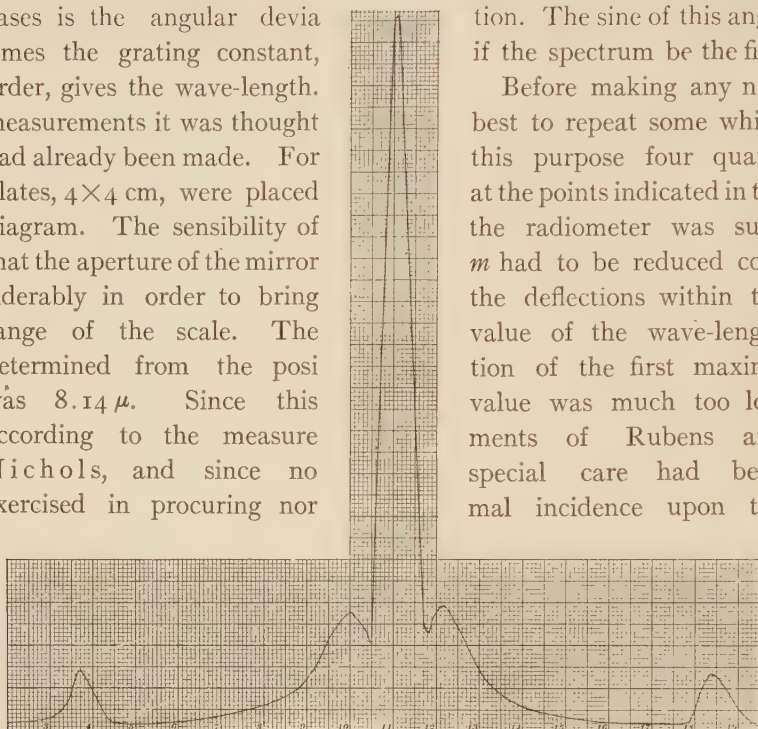


FIG. 7.—Potassium Dichromate.

Scale: Abscissae, 1 small division = $2'$;
Ordinates, 1 small division = 1 mm on radiometer scale.

grating, the adjustments were all made again in as careful a manner as possible. The mirror m was moved until the diameter of the beam reflected across the room remained constant. In order to secure normal incidence a long narrow mirror with the silvered side next to the wires was placed carefully on the grating above the portion which was being used, and the mirror m turned about a vertical axis until the reflected image of the filament lay in the prolongation of the filament itself. The wires of the grating and slit S were

arranged parallel to each other by means of a fine, silk-thread plumb-line viewed through a telescope. The filament was then adjusted parallel to S . These adjustments were of course all made after the spectrometer table had been leveled. The quartz surfaces were then put in place, and the maxima on either side of the central image determined as follows. The observer at the slit S moved the spectrum across the slit S by turning the rod L until he was sure he had passed beyond the maximum in the first order spectrum. Then he moved the spectrum in the reverse direction as the action of the radiometer. When it became evident that the maximum was approaching the slit of the spectrometer, the screen K was lowered and when the maximum reached K was raised and was then again lowered and so on until the first spectrum of the central image was in the position of maximum deflection of the position of maxi-

positions of the first maximum central image determined. H moved the spectrum the rod L until he was sure of the position of the maximum. L was then turned slowly the observer watched the spectrum through the telescope T . that the maximum was in the position of the spectrometer, the screen K was raised to steady conditions were reached. K was then lowered and another setting made, and the maximum deflection settings at

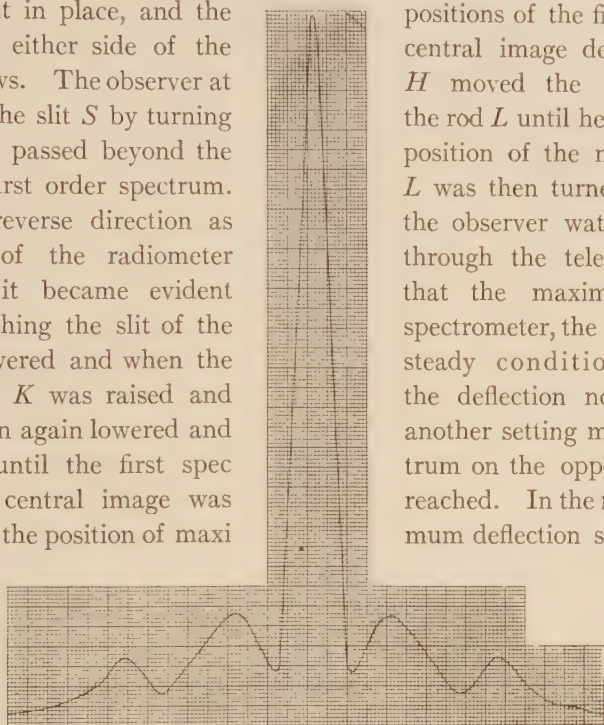


FIG. 8.—Copper Sulphate.

Scale: Abscissae, 1 division = 1μ ;
Ordinates, 1 division = 1 mm of deflection.

every minute of arc on the spectrometer were made, care being taken always to make the setting by turning L in the same direction. In order not to bias the judgment no differences between spectrometer readings were taken until the observations were completed. Regarding the position of the central image as the zero on the spectrometer, the positions of the maxima were on the one side $1^\circ 58'$, on the other $1^\circ 58'$. For a grating constant equal to 0.2414 mm the value of the wave-length for this angle is 8.28μ .

Although two different gratings and four different sources, namely, a Nernst filament 110-V., A. C., a Nernst filament 76-V., D. C., a Welsbach mantle, and a hot used, I have been totally higher than this. It is with these results, my only excuse diligently for a source of find none. Objection might Nernst filament without a necessary to say that the obtained when the filament and slit was $8.25\ \mu$. Fre mined the positions of the order on the left, the central the right, the spectra were and the positions of the three with the same result within vation, thus always showing went no change during a

Aschkinass¹ has found strongly in the neighbor which value he obtained by The value I have obtained

The remainder of this consideration of substances been determined before. It crystals with any reference

platinum wire have been unable to obtain a value some hesitation that I give being that I have sought error and have been able to be raised to the use of a slit. To this it seems only value of the wave-length was replaced by a Welsbach quently after having deter-three maxima, i. e., the first image and the first order on again shifted across the slit maxima again determined, the limits of error of obser-that the apparatus under-series of observations.

that marble (white) reflects hood of wave-length $6.7\ \mu$, the method of *Reststrahlen*. for white marble is $6.77\ \mu$. paper will be devoted to a whose *Reststrahlen* have not was not possible to cut the to the optic axis, nor does

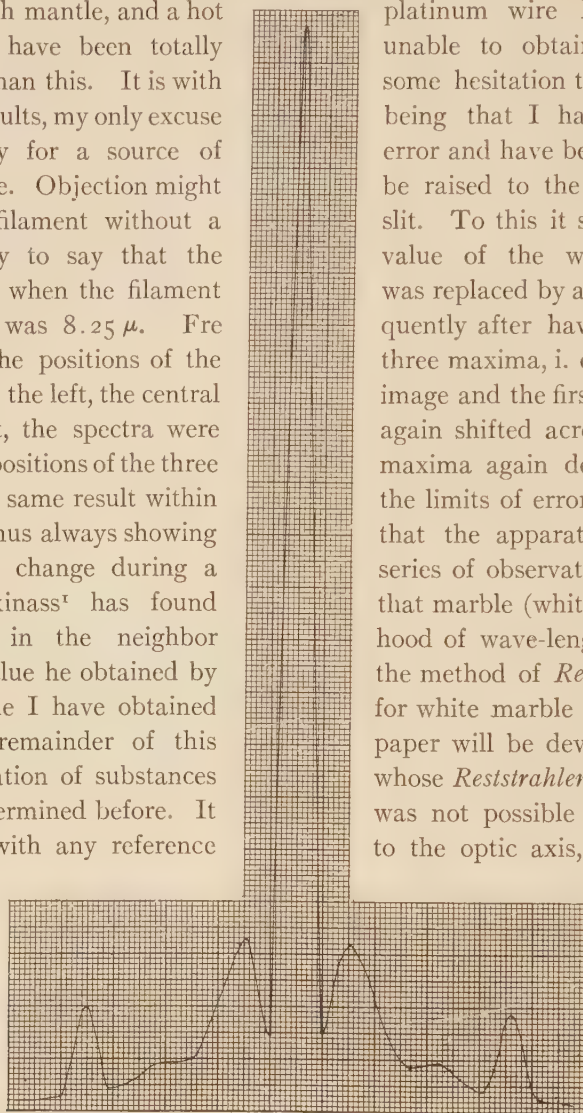


FIG. 9.—Tartaric Acid.

Scale: Abscissae, 1 division = 1';

Ordinates, 1 division = 2 mm of deflection.

¹ *Annalen der Physik*, **65**, 241, 1898.

this seem necessary, for the experiments with quartz have shown that the phenomena are independent of the direction in which the faces are cut. Furthermore, owing to the small size of the crystal, the number of surfaces used has been uniformly only three.

Potassium dichromate.—readily take a high polish. obtained varied from three The curve is plotted in the measurements of this kind ings as abscissæ and deflec ordinates. The curve is about the maximum deflec central image.

In order to make clear as the curves that follow, I shows the distribution of direct current Nernst glower from the central image out order spectrum. This curve tuting for S_1 , S_2 , S_3 , silver-maximum deflection in the because it was too large to withstanding the fact that

Crystals of this substance In area the surfaces to six square centimeters. way usually employed in with spectrometer read-tions of the radiometer as therefore symmetrical tion corresponding to the

the meaning of this as well have added another which the energy from a 76-volt, in the grating spectra, beyond 10μ in the first-was obtained by substi-on-glass mirrors. The central image is not given be read on the scale, not-the aperture of the mirror

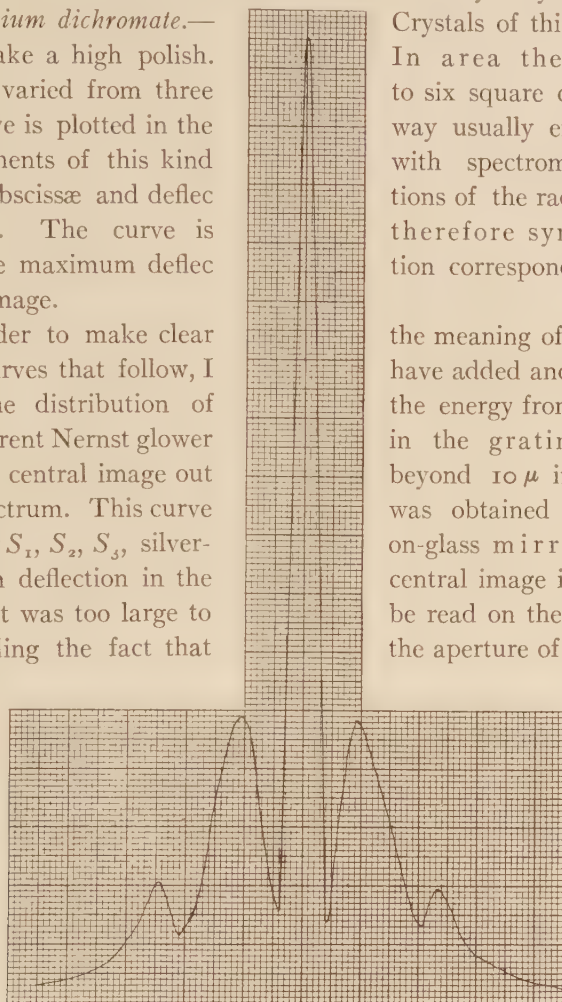


FIG. 10.—Ammonium Chloride.

Scale: Abscissae, 1 division = 2μ ;

Ordinates, 1 division = 7 mm of deflection.

The central maximum is drawn to one-half scale.

m was cut down to the size of a pin head. $ABCD$ shows the energy distribution in the first-order spectrum. B is the point of maximum emission of energy from the source. Its angle of deviation is approximately $20'$, which corresponds to a wave-length $= 1.4 \mu$. Assuming the law $\lambda_m \theta =$ constant, we get for the temperature of the glower $2062^\circ \text{ C. Abs.}$

In all the curves given emission maxima on either side examination of the curves, there is some variation in the central image. This several causes. In the first the filament was not the

herewith we find these emis-
of the central image. An
however, will show that
their position relative to
shifting may be due to
place the current through
same for any two curves;

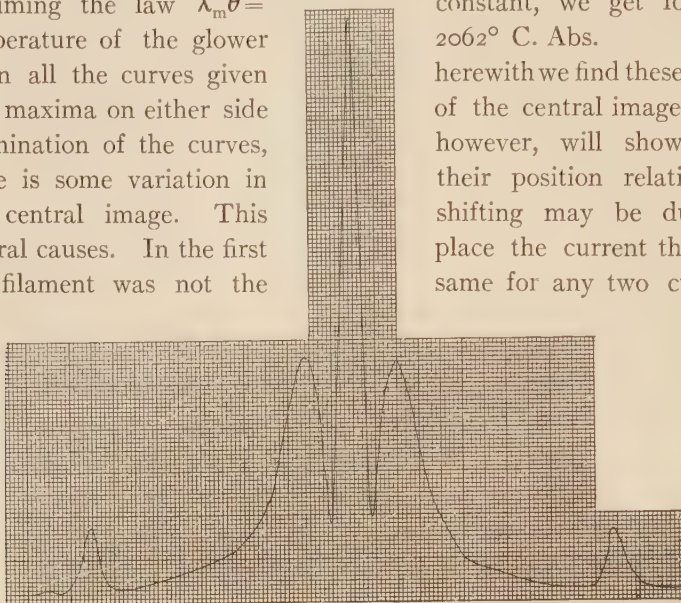


FIG. 11.—Potassium Sulphate.

Scale: Abscissae, 1 division $= 2'$;

Ordinates, 1 division $= 1 \text{ mm of deflection.}$

The central maximum is drawn to one-third scale.

and in the second, if the substance should possess any strong reflecting power in the neighborhood of this maximum, the result would be an apparent shifting of the energy maximum, in either one direction or the other.

We will return to the consideration of the potassium dichromate curve. D and E , then, are the maxima due solely to the energy emission of the source. By increasing the number of surfaces these could doubtless be cut out, as was found to be the case with quartz. With three quartz surfaces these maxima occur in approximately the same position as in all the curves here given, but by increasing the number of surfaces to four they disappear, although the curve

slopes off gradually at the base on either side of the central image and does not fall to zero abruptly as does the one given by Rubens and Nichols for four surfaces. The cause of this difference is undoubtedly to be found in the greater sensitiveness of the instrument used in this work. A spectra of the waves most substance, or what has been comparing this curve with source it is to be remem the mirror *m* in this case in the case of the energy-ver mirrors it was not over

The angles of deviation $2^{\circ} 26'$ respectively. The to $2^{\circ} 27'$ is 10.31μ .

Copper sulphate.—The surfaces were similar to The curve presents the peering different because of to which the two are

and *C* are the first-order strongly reflected by the termed the *Reststrahlen*. In the energy-curve of the bered that the aperture of was the total aperture, while curve obtained with the sil-a millimeter.

of *A* and *C* are $2^{\circ} 28'$ and wave-length corresponding

quality and size of these those of the dichromate. same peculiarities, only ap-the difference in the scales drawn.

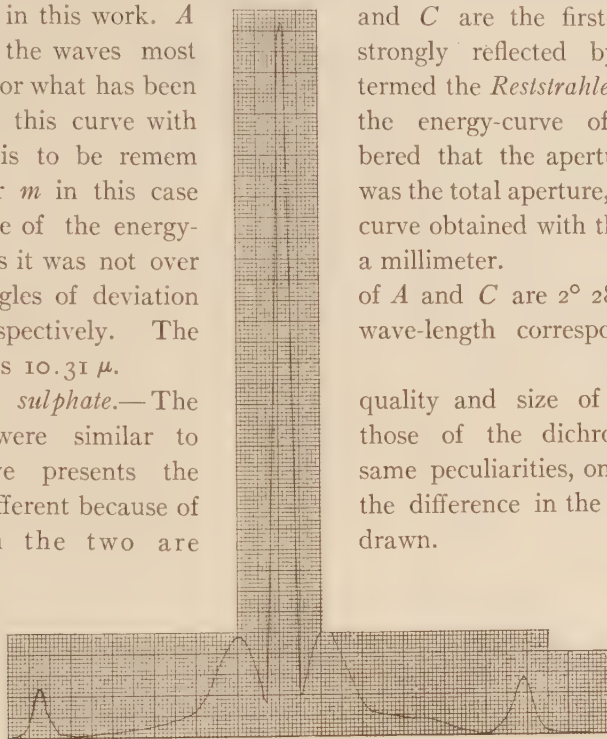


FIG. 12.—Potassium Bisulphite.

Scale: Abscissae, 1 division = $2'$;

Ordinates, 1 division = 2 mm of deflection.

Positions of the maxima:

Energy maxima,	$18\frac{1}{2}'$ and $20\frac{1}{2}'$
<i>Reststrahlen</i> maxima,	$47\frac{1}{2}'$ and $46\frac{1}{2}'$

The wave-length corresponding to $47'$ is 2.30μ .

Tartaric acid.—The reflecting surfaces obtained in this case were exceptionally good, but the areas of the surfaces were very small, not over 3 sq. cm for the largest S_3 .

Positions of the maxima:

Energy maxima, 19' and 20'
Reststrahlen maxima, 1° 21' and 1° 22'

Wave-length corre

5.72 μ .

Ammonium chloride.—
Ammonium chloride were not so
larger than in the above

Positions of the maxi

Energy maxima,
Reststrahlen maxima,

Wave-length corre

Potassium sulphate.—
same were not at any dis
ones, however, were found
that surfaces were readily
Although the surfaces
somewhat discontinuous,
reflected was amply suffi
ments. The area of the
cm.

sponding to 1° 21½' is

The surfaces of ammo-
good, but were much
cases.
ma:

19' and 21'
47' and 48'

sponding to 47½' is 3.44 μ .
Large crystals of this sub-
posol. Aggregates of small
which were so compact
polished on them.
obtained in this way were
the amount of energy
cient for the measure-
largest was not over 4 sq.

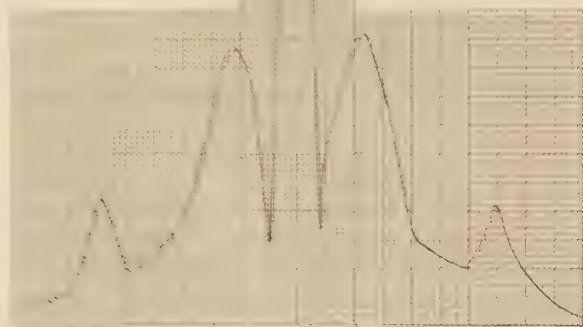


FIG. 13. - Potassium Ferrocyanide.

Scale: Abscissae, 1 division = 1';

Ordinates, 1 division = 1 mm of deflection.

The central maximum is drawn to one-third scale.

Positions of the maxima:

Energy maxima, 21' and 21'
Reststrahlen maxima, 2° and 2°

Wave-length corresponding to 2° is 8.42μ .

Potassium bisulphite.—These surfaces were also obtained by polishing aggregates of small crystals as in the last case.

Positions of the maxima:

Energy maxima, $20'$ and $21\frac{1}{2}'$
Reststrahlen maxima, $1^{\circ} 56'$ and $1^{\circ} 58'$

Wave-length corresponding to $1^{\circ} 57'$ is 8.21μ .

Potassium ferrocyanide.—The somewhat cheesy nature of potassium ferrocyanide rendered it difficult to obtain surfaces of sufficient reflecting power. Success was finally obtained and the accompanying curve shows the results.

Positions of the maxima:

Energy maxima, $22'$ and $24'$
Reststrahlen maxima, $1^{\circ} 9'$ and $1^{\circ} 9'$

Wave-length corresponding to $1^{\circ} 9'$ is 4.84μ .

SUMMARY OF RESULTS

Wave-lengths of the *Reststrahlen* from various substances below 11μ determined from measurements on first-order spectra.

Substance	Source	Wave-Lengths
Quartz.....	76 V., D. C. Nernst Filament	8.28μ
Marble (white).....	76 V., D. C. Nernst Filament	6.77μ
Potassium dichromate.....	110 A. C. Nernst Filament	10.31μ
Copper sulphate.....	110 A. C. Nernst Filament	2.30μ
Tartaric acid.....	76 V., D. C. Nernst Filament	5.72μ
Ammonium chloride.....	" " "	3.44μ
Potassium sulphate.....	" " "	8.42μ
Potassium bisulphite.....	" " "	8.21μ
Potassium ferrocyanide.....	" " "	4.84μ

The following table, giving the substances whose *Reststrahlen* have been determined by others, is added for the sake of completeness.

Substance	By Whom Measured	Wave-Lengths in μ
Quartz.....	Rubens and Nichols	8.50, 9.02, 20.75
Mica.....	Rubens and Nichols	9.20, 18.40, 21.25
Fluorite.....	Rubens and Nichols	24.4
Rock salt.....	Rubens and Aschkinass	51.2
Sylvine.....	Rubens and Aschkinass	61.1
Marble.....	Aschkinass	6.69, 29.4

Before concluding I wish to say a few words in regard to some experiments which have been made with a view to determining whether or not the waves in the neighborhood of 8.3μ can be elliptically polarized by reflection from a quartz surface. The fact that one is compelled to keep both the source and the radiometer in fixed positions has rendered the necessary adjustments very difficult. For polarizer and analyzer I have used two small fluorite plates about $2\frac{1}{2}$ centimeters square. At this wave-length fluorite reflects only about 2 per cent. of the energy incident upon it; consequently, by the time the radiations have suffered reflection at two fluorite, and three quartz surfaces there is very little energy left at one's disposal. Although I have not succeeded in carrying out the experiment to a definite conclusion the preliminary tests have shown that the radiometer is sufficiently sensitive to detect the small quantity of energy with which one has to deal. I therefore hope to obtain some results which will be conclusive on this point.

To Professor Joseph S. Ames, under whose direction this work has been done, I am greatly indebted, chiefly for his valuable suggestions and his unfailing interest.

JOHNS HOPKINS UNIVERSITY,
Baltimore, June 1905.

BIOGRAPHICAL SKETCH

James Temple Porter was born in Bath County, Virginia, September 29, 1873. At the age of thirteen he entered the preparatory department of St. Johns College, Annapolis, Md. In the fall of 1891, after having been out of school for a year and a half, he matriculated at Randolph-Macon College, Ashland, Va., from which institution he received the degree of Bachelor of Arts in June 1895. The two following years were spent, one as instructor in Martha Washington College, Abingdon, Va., and the other as instructor in Randolph-Macon Academy, Front Royal, Va. In the fall of 1897 he returned to Randolph-Macon College as a student, and in June 1898 was admitted to the degree of Master of Arts. From September 1898 to June 1901 he was again instructor in Randolph-Macon Academy. In October 1901 he entered Johns Hopkins University, where, during the past four years, he has as a graduate student in the Department of Physics attended courses under Professors Ames, Wood, and Bliss, and Associate Professors Whitehead and Cohen. From 1901 to 1903 he held a Virginia Scholarship, from 1903 to 1904 a position as Student Assistant in Physics, and during the present session has held a Fellowship in the same department.

